PEMBeyond

PEMFC system and low-grade bioethanol processor unit development for back-up and off-grid power applications

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Risk management plan

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Summary

This document describes the risk management procedure applied in PEMBeyond project. The process includes risk identification within the project consortium, quantitative risk assessment and response planning, followed by risk monitoring, control and reporting.

The above procedure was used to identify the risks related to PEMBeyond project, and based on the analysis results risk response planning was carried out for the most significant threats. The main risks are primarily related on reaching the efficiency, cost and hydrogen quality goals, also having direct correlation between each other. The closed risks and lessons learnt were also reported.

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1. Introduction

1.1 Executive summary

This document describes the risk management procedure applied in PEMBeyond project. The process includes risk identification within the project consortium, quantitative risk assessment and response planning, followed by risk monitoring, control and reporting.

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1.2 Purpose of the risk management plan

The aim of this document is to provide a way for the project management to identify key risks related to achieving the project goals, both technical and economical as well as maintaining the project schedule and budget.

In addition to defining the procedures, the identified and assessed risks are listed in Section 3. For the risks identified most critical for the project success, clear actions are defined to keep the risks under control (Section 4). Furthermore, risks that have already realised and/or closed are listed and reviewed in Section 5.

2. Risk management procedure

This section defines the risk management procedure applied in PEMBeyond project, including risk identification and analysis, response planning, monitoring and reporting.

2.1 Risk identification

The risk identification is based on discussions and brainstorming sessions held within the project meetings and direct input from the coordinating and other parties in the consortium, stemming from strong experience of similar development and demonstration projects. No third parties are used in this project to identify risks, except for the FCH-JU program office.

2.2 Risk analysis

The risk analysis and assessment is based on a qualitative method, where the identified risks are rated based on their probability/likelihood and impact to the project. The probabilities are defined in three categories as follows: *Unlikely* ($p < 0.3$), *Possible* ($0.3 \leq p < 0.7$), *Probable* ($p \geq 0.7$). The impacts and consequences are rated from *Low* through *Harmful* to *Serious*. The severity of risk based on the probability and impact is determined based on the risk matrix provided in Table 1, ranging from *Insignificant* to *Intolerable* risk.

Table 1: Risk matrix employed in the quantitative risk assessment

RISK EVALUATION		Impact / consequences		
		LOW (1)	HARMFUL (2)	SERIOUS (3)
Likelihood	PROBABLE (3)	3 Moderate risk	4 Significant risk	5 Intolerable risk
	POSSIBLE (2)	2 Low risk	3 Moderate risk	4 Significant risk
	UNLIKELY (1)	1 Insignificant risk	2 Low risk	3 Moderate risk

2.3 Risk response planning

The response plans are targeted to lower the significance of the risk in question. For each risk that needs to be acted upon, the project consortium will identify ways to prevent the risk from occurring or reducing its impact or probability. In particular, the following risk management actions will be considered:

- Avoid: Eliminate the threat to the project by eliminating its cause
- Mitigate: Seek ways to reduce to probability of the threat
- Accept: Do nothing to alleviate the threat
- Contingency: Define actions in response to the risk realising
- Transfer: Move the ownership/responsibility of the risk to a third party

In practice, the response plans will consist of combinations of the above actions.

2.4 Risk monitoring, control and reporting

Significant risks will be reported as part of the project WP-level reporting procedures. Project coordinator will monitor risks overarching work packages. The project coordinator together with the consortium members will ensure that all the relevant risks related to the project outcomes are actively identified and monitored.

The consortium will implement a two stage escalation process to manage the risks related to the project:

1. On the first level the WP leaders are in charge to propose solutions to overcome the problems. In case the problems cannot be solved at WP-level or the there exists a high probability of the risks affecting the whole project, the issue will be brought to General Assembly.

2. If within a WP a technical or timeline problem could not be solved, the General Assembly will discuss the consequences for PEMBeyond project. As a result the General Assembly will set up a specific contingency plan to align the project with the original timeline. In all cases the European Commission will be informed about the measures and the resulting consequences for PEMBeyond project.

Figure 1 illustrates the 2-stage risk reporting and management process. During the project duration, new significant risk will be reported to project management, who will keep track of the risks under surveillance.

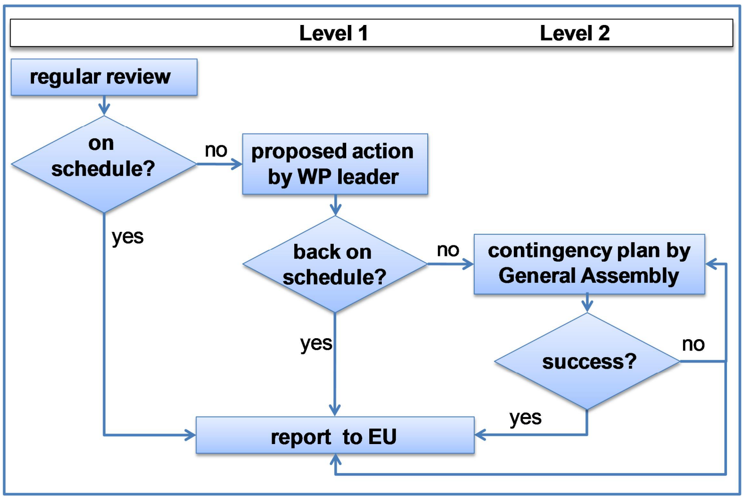

Figure 1: Flow diagram of monitoring, response and reporting actions with respect to risks related on project schedule.

2.5 Closing a risk

In case a risk is no longer valid, the risk event has occurred, or the risk is no longer considered a risk, the risk will be closed and removed from the list of monitored risks.

For closing a risk, it is first reported to the project coordinator, who together with the project consortium declares the risk closed in a project meeting. At risk closure, any secondary risks that might arise from the event are also assessed, and if needed, added to the monitoring list.

3. Risk assessment

The risks identified and collected within the project consortium meetings and other communication are provided in Table 2, including short descriptions. The risks are divided in nine categories, based on the project WP-structure: Management and implementation (R1), development, integration and demonstration activities (R2-R7), economic and environmental targets (R8), and dissemination and exploitation (R9).

The probability and impact of the event is first assessed, leading to a certain risk category as described in Section 2.2. The most significant risks are further assessed with responses and contingency plans in Section 4.

Table 2: Risk identified within the project and their quantitative assessment.

Issue/Challenge				
Management and implementation	Potential impact	Probability	Impact	Risk
R1.1 Underestimation of time needed to produce deliverables	Tasks not completed and deliverables not submitted on time.	3	1	3
R1.2 Underestimation of effort needed to complete activities	Project resources and budget overrun.	1	3	3
R1.3 Lack of experience and qualifications of staff involved	Poor quality of the results and damage for project equipment and personnel.	1	3	3
R1.4 Issues related to partners communication	Coordination problems, disputes between partners, lack of information or misinformation leading to delays.	1	2	2
R1.5 Risks stemming from multidisciplinary partners	Failure to successfully transfer knowledge between partners, ambivalence of project goals between partners of different background.	1	2	2
R1.6 Partner bankruptcy or withdrawal	One of the partners will have to part the consortium, making some tasks impossible to complete and undermining the project success.	1	3	3
R1.7 Key person withdrawal	A key person in the project will not be able to perform the allocated tasks. Resources need to be allocated from other tasks, new persons recruited and trained for the tasks. Delays in tasks.	3	2	4
R1.8 Stack or subsystem development schedule	Development tasks take longer to complete due to unexpected problems. Integration tasks delayed.	2	2	3

R1.9 Complete system integration and testing schedule	Complete system integration and testing takes longer to complete due to unexpected problems. Reaching the 1000-h operation not possible within the remaining project months. Key project results undermined.	1	2	2
Stack development	Potential impact	Likelihood	Impact	Risk
R2.1 Efficiency and durability	Low efficiency could undermine the efficiency target of the complete system, whereas low durability increases the operation costs.	1	2	2
R2.2 CO tolerance	Low CO tolerance decreases stack efficiency and durability. See R2.1.	2	2	3
R2.3 Freeze SU	Stack not able to freeze start without auxiliary heating, requiring additional heating systems increasing system cost.	3	1	3
FCS development	Potential impact	Likelihood	Impact	Risk
R3.1 BoP and/or power electronics efficiency	Chosen components and BoP design not optimal, resulting in lower net power lower complete system efficiency.	1	2	2
R3.2 Low grade fuel compatibility	System control algorithms not able to cope with high H2 inert content or impurity effects. Low system efficiency.	1	2	2
R3.3 Cold operation	Problems with battery, valves, blowers, icing inside components, membrane humidifier. Low humidity causing problems with sufficient stack humidification. Lower efficiency or system failure.	2	1	2
R3.4 Electrical failure	A failure in the power electronics and supply system. Damage to components, equipment and personnel.	1	3	3
Fuel Processor development	Potential impact	Likelihood	Impact	Risk
R4.1 Efficiency	Low conversion efficiency from bioethanol to syngas will lower the complete system efficiency, although the heating value can be utilized by afterburners.	1	2	2
R4.2 Durability and compatibility with crude bioethanol	Reformer or WGS performance decays or catalyst not stable in long term with crude bioethanol. Reduced efficiency, maintenance costs and/or system failure.	2	2	3
R4.3 Product gas quality	Product gas feed quality not good enough for PSA to reach tolerable H2 composition for fuel cell system. Reduced complete system efficiency.	1	2	2

PSA development	Potential impact	Likelihood	Impact	Risk
R5.1 Efficiency	Large portion of hydrogen wasted as off-gas. Can be used to heat the fuel processor lowering ethanol consumption. Reduces overall system efficiency.	1	2	2
R5.2 Product gas quality	CO-content or inert content higher than FCS or stack tolerance. Reduced efficiency, runtime and durability.	2	2	3
R5.3 Durability	Adsorption capacity of the adsorbent reduced. PSA operating with suboptimal cycles. Hydrogen yield and total system efficiency reduced or system inoperable.	1	2	2
Complete system integration	Potential impact	Likelihood	Impact	Risk
R6.1 Integration site availability	If container or site for integration not available early, delays will occur.	1	2	2
R6.2 Subsystem or critical component availability	Delays or unavailability of key components will impose delays in the project schedule.	1	2	2
R6.3 H2 safety	If hydrogen safety aspects are not considered appropriately, a fire or an explosion could cause personnel losses and/or destroy valuable equipment.	1	3	3
R6.4 Fire safety	If fire safety aspects regarding ethanol storage and use are not considered appropriately, a fire could cause personnel losses and/or destroy valuable equipment.	1	3	3
R6.5 Electrical safety	Careless wiring and design of electrical systems may inflict damage on personnel or the components connected in the same circuit.	1	3	3
R6.5 Pressure equipment safety	Flaws in design, assembly and testing of pressurized components may cause danger to personnel or downstream components.	1	3	3
Testing and field trial	Potential impact	Likelihood	Impact	Risk
R7.1 Crude Bioethanol availability	None of the contacted suppliers are able to deliver 1000+ litre quantity required for the field testing. Project key results undermined.	2	2	3
R7.2 Trial site availability	None of the contacted end users are able to provide a suitable field trial site.	1	3	3

R7.3 Subsystem or critical component failure	One of the main subsystems or components goes through a serious failure, yielding the complete system inoperable. Project schedule and budget affected by repairs.	1	3	3
R7.4 Cold operation	Cold climate in field tests causes problems with the integrated system, leading to component failures.	2	3	4
R7.5 Total efficiency or net power target	Due to subsystem, integration or product gas quality issues the targeted efficiency and net power not reached. System cost per kW increases.	1	3	3
Economic and environmental	Potential impact	Likelihood	Impact	Risk
R8.1 Reaching CAPEX targets	High capital expenditure makes the system less attractive for telecom applications. The available market for the system is narrowed down.	1	3	3
R8.2 Reaching OPEX targets	The logistics and maintenance costs of the system do not reach project goals. The available market for the system is narrowed down.	1	3	3
R8.3 Competing technologies	Major breakthrough in battery or H2 storage technology renders ethanol based H2 production useless.	1	3	3
R8.4 Reaching GHG targets	GHG emissions based on the system life cycle analysis are higher than the competing technologies. Attractiveness of the system is significantly reduced. Also relates to the GHG emissions of our feedstock, crude bioethanol. Recycling of Noble metals!	1	2	2
Dissemination and exploitation	Potential impact	Likelihood	Impact	Risk
R9.1 Dissemination target audience	Dissemination activities fail to target the correct audiences. The project may fail to get the expected end user satisfaction.	1	2	2
R9.2 Poor dissemination towards the general public	Poor dissemination towards general public and policymakers. General awareness of the project technology remains low, reducing the number of possibilities for future applications.	1	2	2
R9.3 Poor common promotion and dissemination actions	Dissemination actions are too few and have poor quality. Poor impression of the full potential of developed technology and project results.	1	3	3
R9.4 Quality and validity of the results	Bad scientific principles or workmanship in technical tasks yields the results questionable.	1	3	3

R9.5 Exploitation of the results	Partners are not able to fully harness the project outcomes. Public research funds used inefficiently.	1	3	3

4. Response planning

Table 3 provides response plans to the risks considered most critical for the project's success. Overall, the main risks in the project are related to technology development activities, including development of stacks, subsystems and system integration. With experienced project partners, the issues can be solved with high probability, as explained in the response plans of each risk considered. However, the risks may still affect the project schedule.

The risks related to hydrogen quality, efficiency and costs structure can be seen overarching throughout the project and also correlate amongst themselves. Extra effort from project management will be focused on monitoring these overarching risks.

At the moment, the project does not have any risk contingency budget, thus some of the risks resulting in economic challenges have to be accepted. The only notable action on top of monitoring is reallocation of project resources from other tasks that are not considered as critical for the project's success. Extension of project duration is an option provided that the budget will remain the same.

Table 3: Response planning on the risks identified as most critical for the project.

Issue/Challenge			
Management and implementation	Potential impact	Risk	Actions
R1.1 Underestimation of time needed to produce deliverables	Tasks not completed and deliverables not submitted on time.	3	**Mitigate + Accept** Partners are kept aware of the deadlines in frequent project meetings. Delays on single deliverables may be accepted as long as project overall stays on schedule.
R1.2 Underestimation of effort needed to complete activities	Project resources and budget overrun.	3	**Mitigate + Accept** Project budget is overviewed in the project preparation phase and at mid-term review. Risk to budget being overrun is carried by partners.
R1.3 Lack of experience and qualifications of staff involved	Poor quality of the results and damage for project equipment and personnel.	3	**Avoid + Mitigate** Only highly trained professionals used and/or sufficient amount of time used for introduction of new employees.
R1.6 Partner bankruptcy or withdrawal	One of the partners will have to part the consortium, making some tasks impossible to complete and undermining the project success.	3	**Mitigate + Accept** The partner in questions should distribute information to others, so search for a replacing party can be started as soon as possible.

R1.7 Key person withdrawal	A key person in the project will not be able to perform the allocated tasks. Resources need to be allocated from other tasks, new persons recruited and trained for the tasks. Delays in tasks.	4	**Mitigate + Accept** Positive atmosphere, interesting tasks and employee workload management will keep Information on different task should be well distributed within employees of each partner, to prevent loss of critical information. However, having too much redundancy in the work will decrease productivity.
R1.8 Stack or subsystem development schedule	Development tasks take longer to complete due to unexpected problems. Integration tasks delayed.	3	**Mitigate + Contingency** The delay can be partly overcome by rearranging the complete system integration work.
Stack development	Potential impact	Risk	Actions
R2.2 CO tolerance	Low CO tolerance decreases stack efficiency and durability. See R2.1.	3	**Contingency + Accept** FCS level CO mitigation methods may be applied by VTT and Genport. As after the first 3 hours of operation at 5 kW, the system power is lowered to 2 kW and stacks are able to tolerate a much higher level of CO. The active surface area will also regenerate during shutdown periods, which can be used as an advantage. The 2nd generation MEAs can also help to alleviate the problem.
R2.3 Freeze SU	Stack not able to freeze start without auxiliary heating, requiring additional heating systems increasing system cost.	3	**Contingency** This can be taken into account during the BPP design process, to reduce the thermal capacity of the stack and coolant. FCS level heat-up methods may be used.
FCS development	Potential impact	Risk	Actions
R3.4 Electrical failure	A failure in the power electronics and supply system. Damage to components, equipment and personnel.	3	**Avoid + Mitigate** Deployment of only specialized personnel in development, building and testing of the power electronics. Implementation of self-test algorithms into FCS to monitor the proper functioning of battery and power electronics.

Fuel Processor development	Potential impact	Risk	Actions
R4.2 Durability and compatibility with crude bioethanol	Reformer or WGS performance decays or catalyst not stable in long term with crude bioethanol. Reduced efficiency, maintenance costs and/or system failure.	3	**Avoid + Contingency** The reformer catalyst should be tested first in small scale with crude bioethanol to verify the stability and correct reaction conditions. After this, crude bioethanol may be used in the integrated fuel processor. Before certainty, only pure bioethanol used in testing. If catalyst deactivation is observed, the reaction conditions can be tuned for more stable region, but this may reduce the reformer efficiency.
PSA development	Potential impact	Risk	Actions
R5.2 Product gas quality	CO-content or inert content higher than FCS or stack tolerance. Reduced efficiency, runtime and durability.	3	**Mitigate + Contingency** UPorto continues adsorbent development in parallel with HyGear delivering the prototype PSA, reducing the risk of too high CO content. Also vacuum pumps can be used in the PSA for increased CO adsorption. FCS level CO mitigation methods may be applied by VTT and Genport.
Complete system integration	Potential impact	Risk	Actions
R6.3 H2 safety	If hydrogen safety aspects are not considered appropriately, a fire or an explosion could cause personnel losses and/or destroy valuable equipment.	3	**Avoid + Mitigate** Measurements and the final integration are designed in way that effectively minimizes probability of H2 accidents. HAZOP document prepared for the complete system.
R6.4 Fire safety	If fire safety aspects regarding ethanol storage and use are not considered appropriately, a fire could cause personnel losses and/or destroy valuable equipment.	3	**Avoid + Mitigate** Ethanol storage decoupled from H2 risks, insulation/heat shielding used if needed. Sufficient ventilation installed for ethanol container.
R6.5 Electrical safety	Careless wiring and design of electrical systems may inflict damage on personnel or the components connected in the same circuit.	3	**Mitigate** Electrical connections of the high voltage lines done by certified electricians. Cable connections double-checked with multimeter before powering up.

R6.5 Pressure equipment safety	Flaws in design, assembly and testing of pressurized components may cause danger to personnel or downstream components.	3	**Transfer + Mitigate** Pressure vessel certification and inspection done by third party, or pressure vessels rented from third party. High volume components should comply with PED. Pressure testing done for in-house made piping and connections.
Testing and field trial	Potential impact	Risk	Actions
R7.1 Crude Bioethanol availability	None of the contacted suppliers are able to deliver 1000+ litre quantity required for the field testing. Project key results undermined.	3	**Mitigate + Contingency** Mitigation by contacting multiple producers early on. Analysis of crude bioethanol samples to produce large batch of synthetic mix to mimic the sample.
R7.2 Trial site availability	None of the contacted end users are able to provide a suitable field trial site.	3	**Contingency** Telecom hardware brought to VTT site, system operated outside. Based on previous experience, long travel distance to site is a considerable risk to the project trial schedule, so field trial site should be no further than few kilometres.
R7.3 Subsystem or critical component failure	One of the main subsystems or components goes through a serious failure, yielding the complete system inoperable. Project schedule and budget affected by repairs.	3	**Mitigate + Accept** Due to multiple FCSs, relates to fuel processor and PSA. The project does not have budget for spare parts except for the stacks, thus a part of this risk needs to be accepted. Spare consumables related to piping and wiring is kept available.
R7.4 Cold operation	Cold climate in field tests causes problems with the integrated system, leading to component failures.	4	**Avoid + Mitigate + Accept** Cold testing of the complete system should be done only at the end of the field trial. FCS, most prone to damage can be tested separately inside a climate chamber. All potentially destructive testing should be done after all other tasks with the equipment in question are completed.
R7.5 Total efficiency or net power target	Due to subsystem, integration or product gas quality issues the targeted efficiency and net power not reached. System cost per kW increases.	3	**Mitigate + Accept** Efficiency of each subsystem is monitored early on in the design process and subsystem efficiencies are measured before complete system integration. Delays related to solving subsystem performance issues needs to be accepted.

Economic and environmental	Potential impact	Risk	Actions
R8.1 Reaching CAPEX targets	High capital expenditure makes the system less attractive for telecom applications. The available market for the system is narrowed down.	3	**Mitigate + Accept** As most of the parts of the system are COTS components, cost of the complete system can be kept minimal by simplifications in design. Cost structure is kept in mind during the design process and cost estimates of the system are updated during the project duration.
R8.2 Reaching OPEX targets	The logistics and maintenance costs of the system do not reach project goals. The available market for the system is narrowed down.	3	**Mitigate + Accept** The subsystems will be designed also system durability in mind. For off-grid this is more important than back-up applications.
R8.3 Competing technologies	Major breakthrough in battery or H2 storage technology renders ethanol based H2 production useless.	3	**Mitigate + Accept** Put all effort to design the current system as efficient and cheap as possible. Appearance of other promising alternatives has good impacts on telecom energy industry in general.
Dissemination and exploitation	Potential impact	Risk	Actions
R9.3 Poor common promotion and dissemination actions	Dissemination actions are too few and have poor quality. Poor impression of the project results and potential of the developed technology.	3	**Avoid + Mitigate** The dissemination activities are executed according to a clear plan, reviewed by FCH-JU. A lot of effort is put to showcase the results in international high impact conferences.
R9.4 Quality and validity of the results	Poor scientific principles or workmanship in technical tasks yields the results questionable.	3	**Avoid + Mitigate** Trained professionals used in the research and development tasks. Results published in journals and conferences evaluated through peer-review.
R9.5 Exploitation of the results	Partners are not able to fully harness the project outcomes. Public research funds used inefficiently.	3	**Mitigate** Exploitation actions based on an exploitation plan and roadmap to volume production, reviewed by FCH-JU.

5. Risks realized and closed

So far, the project has faced some issues relating to key persons leaving the project, which have caused rearrangements of the work to other persons involved in the project, causing small delays on some tasks (R1.7). Early in the project, problems faced on the stack and subsystem development have also caused delays (R1.8).

The risk R2.3, considering the stack cold SU capability is closed based on the cold trial tests performed in M22. Risk R6.1 on the integration site availability is also closed.